APPENDIX A

VOLUME CALCULATIONS

A. GENERAL. This section describes recommended practices and procedures for volume calculations and corrections in the measurement of petroleum and its liquid products. The API Manual of Petroleum Measurement Standards should consulted for measurement standards and techniques not discussed here.

B. FUNDAMENTAL PROCEDURE

1. Five basic steps involved in determining standard bulk petroleum quantities are: (1) measure product volume and water bottoms by gauging or metering, (2) determine average temperature, (3) test for density (or API gravity), (4) test for water and sediment, and (5) volume calculations and corrections.

2. Steps 1 and 2 are necessary to obtain data on quantities actually measured in storage tanks and other containers or carriers. Steps 3 and 4 are required for obtaining essential factors and water and sediment levels necessary for volume corrections. Step 5 is the recommended practice to be used in calculating the net quantities at 60°F from the data obtained in steps 1 through 4.

C. MEASUREMENT STANDARDS

1. Density [or API Gravity)

a. The practices and procedures in ASTM D-1298 or ASTM D-4052 shall be used in determining density (or API gravity) unless contracts, tariffs, or similar agreements specify otherwise.

b. Use ASTM D-1250, table 53 (or table 5) to convert observed density (API gravity) to density 15°C (API gravity at 60°F). Increments used in the printed version of the tables for determining density at 15°C (API gravity at 60°F) are 0.25°C (0.5°17) and 2 kg/m3) (0.5° API). Interpolation with temperature is not intended since there is no practical method of interpolation that will produce the accuracy obtainable from the computer version of the tables. However, interpolation with density (API gravity) can be reasonably made. Interpolation of the density (API gravity) is not necessary when the only use of the density (API gravity) measurement is as an entry into table 54 (table 6) in order to obtain a volume correction factor. In all other cases, interpolation is required.

2. Temperature of the product. Determine the product temperature in ‘C (or “F) at the time when gauging or metering occurs IAW ASTM D-1086.

3. Volume Correction. Except when weighting, gross quantities shall be measured and adjusted to 60°F using most recent edition of the ASTM D 1250/API 2540 /IP 200, tables 5 & 6 (tables 52, 53 and 54 where the metric system is used). The “B” designated tables will be used for all products except JP4 and crude oils which will use “A” designated tables and lubricating oils which will use “D” designated tables. When the metric system is used, divide liters at 15°C by 1000 to obtain cubic meters at 15°C; then use table 52 to convert cubic meters at 15°C to barrels at 60°F. Multiply barrels at 60”F by 42 to obtain U.S. gallons at 60°F.

4. Weighing. When weighing, use ASTM D-1250, Volume XI, table 8 to convert pounds to gallons at 60° F (or ASTM D-1250, Volume XIII, table 58 to convert metric tons to gallons at 60°F).

5. Gauging of tanks. Gauging and adjustments shall be IAW ASTM D 1085.

6. Meters. Procedures for calibrating (proving) meters and using meters are in the API Manual of Petroleum Measurement Standard Chapters 4 and 5. Temperature compensating meters will be calibrated IAW American Society of Mechanical Engineers and API Code No. 1101 - Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meters and API Standard 2534 for turbine meters.

D. CALCULATIONS FOR TANK GAUGING

1. Basic Calculations for Tank Gauging

a. Tanks scheduled to receive/issue product shall be gauged and checked for water bottoms before and after receipt/discharge (opening/closing gauge). (See subsection C.5., above).

b. Temperature and density of the product in the tank shall be determined for both opening and closing gauge (see subsections C. 1. and C.2., above).

C. Quantity readings, less water bottoms, shall be separately adjusted to 60°F (15 'C) for all product receipts/issues (see C.5., above).

d. Quantity received shall be computed by subtracting the opening gauge quantity from the closing gauge quantity. Quantity issued shall be computed by subtracting the closing gauge quantity from the opening gauge quantity. For crude and residual fuel oils a deduction may be required for Sediment and Water (S&W) in order to obtain the quantity received. Report results to the nearest whole gallon or to the nearest hundredth of a barrel.

e. Example: The procedures above, including conversion of gallons to barrels, are illustrated below for measurements using the outage method and the B series tables for an issue from a tank.

Gauge	Opening Gauge	Closing Gauge
Reference depth	28' 8"	28' 8"
Outage: Total product/water ht		19'10"
Tape reading	10' 4"	o' 3 1/8"
Bob reading	3' 314"	o' 3 1/8"
Outage gauge	0'7 3/4"	20' 1 1/8"
Water outage	28'5 3/4"	28' 5314"
Temperature, 'F		
Top	51	50
Mid	51	49
Bot	48	48
Average	50	49

Gauge	Opening Gauge	Closing Gauge
Reference depth	28' 8"	28' 8"
Outage Total product/water ht		
Tape reading	10' 4"	19'10"
Bob reading	3' 3/4"	O'3 1/8"
Outage gauge	0'7314"	0'1 1/8"
Water outage	28'5314"	28' 5314"
Temperature, °F:		
Top	51	50
Mid	51	49
Dot	48	48
Average	50	49
LabOratory data:		
Gravity at 60"F		43.3
Suspended water& sediment		0.2
(NOTE: for a receipt, the opening and closing densities could differ)		

Calculation:

Measured quantity (qty):		
Reference depth	28' 8"	28' 8"
Minus outage gauge	10'7314"	20' 1 1/8"
Innage gauge	18' 1/4"	8' 6 7/8"
USG (from capacity table)	954,238	457,982
Free water:		
Reference depth	28' 8"	28' 8"
Minus outage gauge	28'5 3/4"	28'5 3/4"
Innage gauge	2114"	2 1/4"
USG (from capacity table)	10,020	10,020
Measured qty less FW&S	944,218	447,962
Average temperature,°F	50	49
Volume correction factor: (using ASTM D-1250 table 6B, rounding off to nearest 0.5° API)	1.0050	1.0055

Delivered gross qty:		
Gross qty at 60°F	944,218	447,962
	xl .0050	x1.0055
or USG	948,939	450,426
Subtracting	-450,426	
Delivered gross qty @60°F	498,513	
For crude & residual fuel oils:		
suspended S and W:		
From laboratory, %		0.2
Minus allowable amount, %		0.0
Deductible,%		0.2
Deductible qty, USG		997
Net qty delivered@ 60°F:		
USG (498,513 - 997)		497,516
Barrels calculated (497,516 divide by 42)		11.845.62

2. Calculations for Floating Roof Tanks

a. Under normal conditions the roof is in a floating position for both opening and closing gauges. Corrections for the weight of product displaced by the roof need not be made if all the conditions below are met, otherwise both opening and closing gauges must be corrected for roof displacement:

(1) The density at 15°C (or API Gravity at 60°F) is unchanged between the opening and closing gauges, and

(2) The roof remains in a floating position, and

(3) The temperature of the product is the same at opening and closing gauge readings.

b. If the roof rests completely on its supports for both opening and closing gauges (volumes below critical zones), roof correction factors are not applicable because the tank is acting as a fixed roof tank, and no

product displacement occurs.

c. If the roof rests completely on its supports for either the opening or closing gauge (volume below critical zone) and is floating for the other gauge, then a roof correction factor is applied to the gauge where the roof is floating but not to the gauge where the roof is resting on its supports.

d. If the roof is in a partial floating position (the critical zone) for any gauge, the quantity cannot be calculated. Either the roof must be floated using a measured quantity from another tank or, although it is not good operating practice for loss control, environmental or safety reasons, product must be drawn away from the roof so that it rests completely on its supports.

e. Floating **roof capacity tables** indicate the method to be used to calculate the roof displacement quantity.

(1) Shell Capacity Tables, If the capacity table is prepared as a gross or open tank capacity, commonly known as a shell capacity table, the method below is used. This type of table will usually contain a notation similar to: "The quantities listed in this capacity table do not include adjustments to compensate for floating roof displacement." Calculate the quantity equivalent to the roof displacement as follows:

(a) Q = W divided by P (Where Q is gallons equivalent to the roof displacement; W is the weight for the floating roof in pounds. P is the pounds per gallon of product).

(b) The weight of the roof is stamped on the roof manhole plate and printed on the capacity table.

(c) Recommended procedure for calculating the quantity of product at 60°F when the floating roof is resting upon its supports at the opening gauge and floating for the closing gauge:

Weight of floating roof (from capacity table)	126,897
Product gravity at 80"F	32.5
Produet gravity at 60"F (using ASTM D-1250, table 5B)	31.1
Pounds per USG at 60"F (using ASTM D-1250, table 8)	7.246
Roof displacement (126,897 divide by 7.246) USG @ 60°F	17,513

Quantity at 60"F	Opening Gauge	Closing Gauge
Measured volume, USG	103,624	715,615
Produet temperature (tank)	81	80
Volume Correction Factor (using ASTM D-1250, table 6B, rounding off to the nearedincrernenL31 .0" API)	0.9906	0.9910
Net USG @ 60°F (volume x factor)	102,650	709,174
Correction, roof displacement USG @ 60°F	None	-17,513
Correct net @ 60°F, USG/	102,650	691,661
Subtracting		-102.650
Received at 60°F, USG		589,011

(2) Roof as Deadwood. Do not correct for the condition outlined in the previous calculation if a quantity equivalent to the roof displacement has been subtracted from the capacity table as **deadwood.** However, since the roof displacement is calculated for a product of a definite API gravity, corrections must be made for products having different API gravities. Obtain the measured quantity directly from the capacity table, and apply the correction noted on the capacity table for the difference in API gravity. The total correction is the difference between the volumes displaced by the roof at the API gravity of the product and the API gravity for which the "deadwood" deduction on the capacity table was made. The correction is added for a product of lower API gravity and subtracted for one of higher gravity. Recommended procedure for calculating the net quantity of product at 60°F, for the case when the capacity table has been corrected for the roof displacement:

	Opening Gauge	Closing Gauge
Innage gauge	27' 2"	2' 1 1/2"
Water innage	0' 2"	O' 2 1/8"
Temperature, 'F	81	80
API gravity @ 60"F (using ASTM D-1250, table 5B)	48.5	48.5
Observed gravity at tank temp	50.7	50.5
Measured qty barrels	51,043.00	3,730.26
Gravity variation from 47°F	3.70	3.50
Minus correction (3.7 x 3.56)	-13.17	None (roof at rest)
Corrected measured qty, bbls	51,029.83	3,730.26
Volume correction factor (using ASTM D-1250, table 5B, rounding off to the nearest 0.5° API increment)	0.9885	0.9890
		0.9894
Qty at 60"F	50,442.99	3,689.23
Calculated net	46,753.76	
Reported net	46,753.76	

3. Calculations for Variable Vapor Space Tanks. When the contents of variable vapor space tanks are gauged through the gauging pipe by the innage tape

and bob procedure, correct the gauge for the tank pressure or vacuum as determined in inches from the manometer. The manometer is usually filled with a nonvolatile liquid having a specific gravity equal to or nearly equal to that of the product in the tank, in which case the manometer reading needs no correction. Deduct this reading from the innage gauge if the tank is under pressure or add it if under a vacuum. If the specific gravity of the manometer liquid and that of the product are not equal or nearly equal, correct the manometer reading by applying the following formula before deducting the reading from the gauge:

C = R x M divided by P where:

C = corrected manometer reading in inches;
R = manometer reading in inches;
M = Sp gravity of manometer liquid at its atmospheric; and
P = Sp gravity of product at its temperature.

4. Calculations for Conventional Tank Cars. The dome capacity in gallons per inch is shown on the tank car capacity table. If the gauge is reported as shell outage, obtain the measured quantity directly from the capacity table. If gauge is reported as dome innage, calculate the measured quantity by multipl ying the dome capacity per inch by the dome innage and add the resultant quantity to the shell capacity. Calculate residue and free water quantities from the "bottom" range of the capacity table for the respective innage gauges because this section of the table has been corrected for "deadwood. " Recommended procedure for calculating tank car:

Temperature, °F	100
Dome innage, in.	10 1/4
Dome capacity per in. (gal)	11.53
Quantity in dome (11.53x 10 1/4)	118
Shell capacity	10.088
Measured quantity (10,088 + 118)	10,206
Residue innage, in.	2 1/4
Residue qty, gal.	67
Measured qty at 100 corrected for residue (10,206- 67)	10,139
API quantity @ 60"F	12
Volume correction factor	0.9853
Gross qty @ 60°F (10,139 x 0.9853)	9,990
Suspended water and sediment, %	0.72
Deductible SW& S	None
Net qty @ 60"F	9,998

E. CALCULATIONS FOR METERS. When temperature compensating meters are used in determining quantity, the quantity will be determined by subtracting the beginning net meter reading from the ending net meter reading. To determine quantity received when non temperature correcting meters are used, subtract the beginning meter reading from the ending meter reading and adjust the resultant quantity to 60"F (or 15 "C) using the average temperature and density of the product as it passed through the meter.

F. CALCULATION FOR CONVERTING PRODUCT WEIGHT TO VOLUME

1. The conveyance is weighted with and without product using calibrated scales. The difference in weight is the weight of the product.

2. The density (API Gravity) of the product in the vehicle is determined. Correct the observed density (API Gravity) to density at 15°C (60°F) if necessary.

3. Use the corrected density (API) and the latest edition of ASTM D 1250/API 2540/IP 200, table 58 (table 8) to determine the gallons at 60"F per metric ._. tonne (gallons at 60°F per pound) for the product.

4. If the weight is in kilograms, divide by 1000 to convert it to metric tonnes. Then multiply metric tonnes by the factor from table 58 to obtain gallons at 60°F. If the weight is in pounds, multiply by the factor from the table to obtain gallon at 60°F.

G. CONVERTING METRIC TO CUSTOMARY UNITS

1. Liters at 15°C to Barrels and U.S. Gallons at 60 °F. Obtain density at 15°C. Divide liters at 15°C by 1000 to obtain cubic meters at 15°C. Use ASTM D-1250/API 2540/IP 200, table 52 to convert cubic meters at 15°C to barrels at 600F. Multiply barrels at 60"F by 42 to obtain U.S. gallons at 60°F.

2. Metric Tons to Barrels or U.S. Gallons at 60 Obtain density at 15°C. Use the most recent edition of ASTM D-1250/API 2540/IP 200, table 58 to convert metric tons to barrels or U.S. gallons at 60°F. In this case use the factors in the table to obtain both gallons and barrels. Multiplying barrels by 42 or dividing gallons by 42 may give different results.

3. Metric Tons to Long Tons. Multiply metric tons by 0.984206 (factor is from ASTM D-1250/API

2540/IP 200, table 1) to get long tons.

4. Liters at 15°C to Long Tons. Obtain' density at 15°C. Divide liters at 15°C by 1000 to get cubic meters at 15°C. Use ASTM D-1250/ API 2540AP200, table 57 to convert cubic meters at15°C to long tons.

H. VOLUME CORRECTION CALCULATIONS FOR FSII

1. Volume of all bulk shipments of FSII shall be corrected to volume at 60"F or15°C IAW the following procedure:

a. Determine the observed volume and temperature (to the nearest 0.5°F or 0.25°C) using standard gauging procedure.

b. Subtract from the observed temperature of the product either 60"F or 15°C as appropriate.

c. For EGME, multiply the result by 0.00052 for degrees Fahrenheit or 0.00093 for degrees Celsius. For DIEGME, multiply the result by 0.00051 for degrees Fahrenheit or 0.00091 for degrees Celsius. Round the resultant number to four decimal places.

d. Add the figure obtained in step (3) to 1.000.

e. Divide the observed volume of FSII as determined in step (1) by the result of step (4). Round the number so obtained to the nearest gallon or liter.

2. When weight is used as the basis for quantity determination, the conversion factor corresponding to the observed specific gravity at 20°C/20°C shall be divided into the weight to determine the volume in gallons at 60"F (or in liters at 15°C):

Observed Specific Gravity

	g/mL at 20 °C/20°C	kg/L at 15°C	lb/gal at 60°F	kg/gal at 60"F
For EGME:	0.963	0.966	8.057	3.654
	0.964	0.967	8.065	3.658
	0.965	0.968	8.073	3.662
	0.966	0.969	8.082	3.666
	0.967	0.970	8.090	3.670

	g/mL at 20 °C/20°C	kg/L at 15°C	lb/gal at 60°F	kg/gal at 60"F
For DiEGME:	1.021	1.024	8.539	3.873
	1.022	1.025	8.547	3.877
	1.023	1.026	8.556	3.881
	1.024	1.027	8.564	3.885
	1.025	1.028	8.572	3.888